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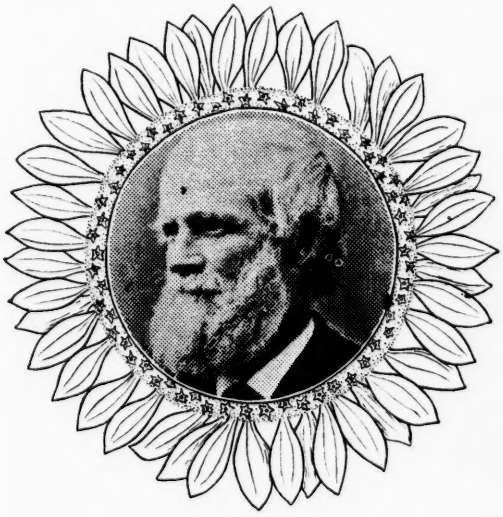

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NOTES ON THE IMMATURE STAGES OF ARKANSAS TABANIDAE †

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The study of Arkansas horse-flies was begun in 1927, and during that and the following year collections of adults were made in several parts of the state. Results of this preliminary study have recently been published (9). The study upon which this paper is based was begun in an effort to determine the larval habitat and seasonal history of the more important species. Data presented in Tables II to XIII show the results obtained from rearing to the adult stage 254 collected larvae, representing fifteen species.

All biological studies on the immature stages of North American Tabanidae have been made in comparatively recent years. Hine (3) published the first extensive notes, based largely on field observations of **Tabanus lasiophthalmus, T. sulcifrons, T. stygius, T. vivax, T. atratus,** and **Chrysops moerens.** One individual of **Tabanus lasiophthalmus** was reared from egg to adult and the remaining species from larva to adult. Marchand (6) collected the world's literature on immature stages of Tabanidae and placed it in one volume, together with certain of his own observations. Jones and Bradley (4) contributed notes on the larvae of **T. atratus, T. annulatus, T. fulvulus, T. trimaculatus, T. imitans, T. wiedemanni, T. reinwardtii, T. fuscopunctatus, C. callidus,** and **C. flavidus,** which they collected and reared to the adult stage in Louisiana. The same authors (5) later collected and reared to the adult stage larvae of **C. obsoletus, C. pikei, T. americanus, T. benedictus, T. cymatophorus, T. lineola, T. melanocerus, T. mexicanus,** and **T. venustus.** They were unable to find larvae of the important economic species, **T. costalis, T. pumilus** and **T. sulcifrons.** Webb and Wells (11) obtained complete life history records on three individ-

*Credit is due Mr. Otto Kumpe, student assistant, who was responsible for much of the routine work connected with this investigation.

† Research paper No. 220, Journal Series, University of Arkansas.

uals of **T. punctifer,** and gathered much valuable information on this species and **T. phaenops.** In addition to biological data, these authors give descriptions of all the immature stages of **T. punctifer** and **T. phaenops,** of the larva and pupa of **T. insuetus,** and of the larva, pupa, and adult of **T. monoensis,** a new species. Cameron (2) collected and reared the larvae of various Canadian species of **Chrysops** and **Tabanus.** He indicated that all **Chrysops** larvae feed entirely on vegetable matter. Phillip (8) gave a summary of improved methods for collecting and rearing tabanid larvae. His methods were developed from those of Marchand (7). Stone (10) reared **Chrysops callidus, C. carbonarius, C. celer, C. cuclux, C. indus, C. moechus, C. monetonus, C. niger, C. striatus, C. vittatus, C. wiedemanni, Tabanus bicolor, T. minusculus, T. nivosus, T. reinwardtii,** and **T. trepidus,** from the larva to the adult. He reared one specimen of **T. atratus** from the egg to the adult stage in a period of 362 days. Descriptions of the larva and pupa are given for each of the above species. Stone takes issue with Cameron regarding the latter's statement that all **Chrysops** larvae feed exclusively on vegetable material. Larvae of **C. celer** and **C. carbonarius** which Stone reared gave evidence of being at least partially carnivorous.

A modification of the method of Marchand (7) was used for collecting larvae. Sieves approximately one foot square, built from screen wire, replaced the smaller kitchen sieves recommended by Marchand. Several handfuls of mud can be placed in one of these and the work thereby hastened. Collected larvae were placed in vials individually for transportation to the insectary. The jelly glass cages used by Hine (3) were adopted for rearing larvae to the adult stage. These consist of half-pint jelly glasses with perforated lids. Half an inch of sand in the bottom of the glass serves to hold moisture and provides a medium into which the larvae can burrow. These cages are set with one edge raised to form an angle of about 15 degrees with the horizontal, so that a moisture gradient varying from moist sand to sand completely saturated with water is formed in each cage.

Earthworms were first given as food, but as the series of tabanid larvae grew it became difficult to find sufficient quantities of this food. Small pieces of meat from the tails of crayfish proved to be an entirely satis-

factory substitute, and since crayfish were easily obtained this type of food was used in all subsequent rearing work. Larvae were fed once every forty-eight hours, and observed daily.

With one exception, the species of **Tabanidae** noted here required no special care at the time of pupation. **Tabanus atratus** will not transform to the pupal stage in the shallow sand of the rearing glass, but requires moist earth three or more inches deep. Larvae not so provided for invariably died without transforming. Thirty-four transformations were secured in this way, while not a single larva pupated in the sand of the rearing jars. All other species reared pupated on the surface of the sand. Under natural conditions the larvae probably move upward just before transformation, until they reach the level, where the continuous phase of the soil is air rather than moisture. This upward migration is probably necessitated by the greater distribution of spiracles on the pupa, and by its comparative immobility. In the rearing cages this migratory instinct brings the larva to the surface of the sand before its air and moisture requirements are satisfied.

Larval Habitat

During the course of this study, 435 larvae were collected, 428 of which were taken within eighteen inches of the water's edge of ponds or small watercourses. Three larvae were taken in a marshy area near a small stream, and four were found in decaying oak logs. Efforts to find larvae in other situations have so far been without result, but it seems certain that large numbers of larvae do occur in places entirely removed from permanent water. Larvae of **Tabanus costalis, T. pumilus,** and **T. sulcifrons** were not taken during the course of this investigation, although these species are extremely numerous as adults. Examination of the soil in pastures where adults of these species were present in outbreak proportions has never revealed the presence of their larvae. That tabanid larvae of certain species do live away from water is shown by the observations of Brimley (1), who has on several occasions taken larvae of **T. fronto** from the soil of his garden. Larvae of various species are occasionally taken under logs, stones, and other objects on overflow land which remains moist throughout the year.

The larvae of only two species have been found

under water in Arkansas. Larvae of **Tabanus vivax,** the river horse-fly, have been found in numbers under stones submerged in from two to six inches of water in small streams. **Tabanus vivax** has been observed ovipositing on stones projecting above the surface in such streams, and hundreds of its egg masses have been seen. Hine (3) has reared **T. vivax** from larvae collected under similar conditions. A larva taken from rice roots in a flooded field on June 25, 1930, produced an adult of **C. flavidus** on August 27, 1930. Several other larvae taken from flooded rice fields were thought to be those of **C. flavidus.** Jones and Bradley (4) took the larvae of **C. flavidus** and **C. callidus** on the mud floor of a pond under a foot of water.

Four white larvae were collected from decaying oak logs. Two of these produced adults of **T. annulatus.**

The type of soil composing the borders of a pond or stream appears to affect its tabanid population. Soils which are loose, or which contain a large amount of gravel, appear to be favorable to tabanid larvae, while exceedingly compact or hard soils are unfavorable. Borders composed of sticky clay have always been found entirely devoid of larvae, even though adults were numerous in the vicinity during the previous summer. Extremely sandy soil appears to be unfavorable to the larvae.

In northwest Arkansas it has been observed that upland spring-fed ponds or brooks harbor a tabanid fauna different from that of the sluggish or stagnant waters of the lowlands. In general, the species of economic importance in Arkansas seem to prefer lowland situations where ponds and water-courses are not spring-fed. Table I, based on collected larvae which have been reared to the adult stage, shows the preference for lowland situations as exhibited by three species.

Table I. Tabanidae. Preference of three species for lowland situations, based on collections made in 1930.

Species	No. from border of spring-fed ponds	No. from border of lowland ponds
Tabanus atratus	1	27
Tabanus lineola	0	14
Chrysops callidus	1	161

BIOLOGICAL DATA

The Genus Chrysops

Chrysops larvae have been taken most frequently during March, April, and May. During the summer they are seldom seen, probably because of their very small size at this season. They are often found in company with **Tabanus** larvae, and may easily be confused with them when both are small. According to Stone (9), the larvae of these generally may be distinguished by observing the apical antennal segment, which in **Chrysops** larvae is much longer than the preceding segment. In **Tabanus** larvae the apical antennal segment is never longer, and usually is much shorter, than the preceding segment.

During the course of this study, the species **callidus, celer, flavidus, obsoletus, pikei, vittatus,** and **niger** have been taken as larvae, and reared to the adult stage.

Chrysops callidus Osten Sacken

This fly was the most numerous species of **Chrysops** in Washington County, Arkansas, during 1930. The first larvae were collected in March and they continued to be abundant until after the first week in May, when a rapid decline occurred. Collections of larvae, pupae, and eggs were made as follows:

March 17	60 larvae
April 4	152 larvae
April 23	40 larvae, 6 pupae
May 8	68 larvae, 21 pupae
May 19	7 larvae, 2 pupae, and 50 egg masses
May 30	1 pupa, no larvae or eggs
June 4	no larvae or pupae, 1 egg mass

Only one adult was taken in this vicinity during the entire season, so that adult records were obtained only from reared individuals. Emergence records for the 162 adults obtained are shown in Table II. Since the earliest pupae were obtained in the laboratory on April 2, or exactly three weeks before the first pupa was found in the field, it seems logical to assume that adult emergence also occurred from two to three weeks earlier in the laboratory than in the field. To approximate the date of field emergence, therefore, the dates in Table II should be made three weeks later.

Table II. **Chrysops callidus** O. S. Seasonal emergence of adults as obtained by rearing collected larvae. 1930.

Date	No. of adults emerging	Date	No. of adults emerging
April 7	7	May 4	2
April 8	1	May 5	1
April 9	1	May 12	14
April 11	1	May 14	6
April 12	11	May 16	5
April 13	2	May 17	1
April 14	3	May 21	3
April 15	4	May 22	4
April 16	4	May 23	3
April 17	3	May 24	3
April 18	3	May 25	3
April 19	19	May 28	2
April 21	14	May 29	5
April 22	5	May 30	1
April 23	3	June 2	2
April 24	2	June 3	3
April 25	5	June 4	1
April 27	1	June 5	2
April 28	1	June 6	1
April 29	1	June 7	1
April 30	4	June 9	1
May 1	3		

Eggs were deposited in flat single-tiered masses on the leaves of sweet flag growing in the pond, and were usually found on plants about six feet from the shore. They were creamy white when first deposited, but became entirely black within twenty-four hours. The masses are quite constant in size, averaging between 150 and 200 eggs each. Three masses counted contained 175, 182, and 187 eggs, respectively.

The larvae were concentrated around the pond in a narrow strip about six inches from the water's edge, and were so numerous that six or eight larvae would sometimes be taken in a single handful of mud. The larvae apparently are not cannibalistic, since no evidence of this habit was observed. Larvae of **T. atratus** which were found near-by preyed upon one another freely and probably destroyed many of the **C. callidus** larvae. Larvae kept together in cages were never

observed to attack one another.

Pupae were found in approximately the same location as the larvae, but were not found in large numbers. Some of the larvae apparently migrated deeper into the bank before pupation. Larvae brought into the laboratory always pupated on the surface of the sand in the rearing jars.

Oviposition by this species has been observed on two occasions. This process has been carefully described by Hine (3).

Both larvae and adults of **C. callidus** have usually been taken near lowland ponds.

Partial life history data, based on records of ten typical individuals, are shown in Table III.

Table III. **Chrysops callidus** O. S. Partial life history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
March 17	April 11	April 18	Male
April 4	April 4	April 18	Female
March 17	April 11	April 18	Male
May 8	May 10	May 22	Male
May 8	May 12	May 22	Male
May 16	May 24	June 3	Male
May 16	May 24	June 4	Female
May 20	June 2	June 9	Female
May 5	May 19	May 30	Female
May 5	May 24	June 3	Female

Chrysops celer O. S.

This species was not known to occur in Arkansas until reared from collected larvae. These larvae were taken from the banks of a small pond which is continuously fed by a large spring. They have not been found elsewhere in the state.

Table IV. **Chrysops celer** O. S. Seasonal history as obtained from collected larvae. 1930.

Date collected	Date pupated	Date of emergence	Sex
April 11		April 23	Female
April 11	April 27	May 4	Female

Chrysops flavidus Wiedemann

This species is the most important of its genus in southern Arkansas, but is taken only occasionally in the

northwest section. Its requirements regarding larval habitat appear to be quite flexible. It has been taken from pond banks, and from the mud surrounding rice roots in flooded fields. This species and **Tabanus vivax** are the only ones whose larvae have been taken from situations under water.

Table V. **Chrysops flavidus** O. S. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
March 17		April 16	Male
Taken as pupa,	May 20	May 26	Female
May 16	May 24	June 2	Male
May 16	May 24	June 4	Male
June 10		June 23	Female

Chrysops obsoletus Wiedemann

A few larvae of this small ear fly have been taken from the shores of nearly every pond or stream where collections have been made. It has usually been taken in company with a number of other species, which together with its small size, may account in part for its scarcity. Larvae brought into the laboratory have never been observed to feed, and are reared to the adult stage with difficulty.

Table VI. **Chrysops obsoletus** Wiedemann. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
April 11		April 29	Male
February 24		April 14	Female
April 28	March 26	June 5	Female
April 28	May 23	June 3	Male
May 5	May 24	June 2	Male
May 9	May 29	June 6	Male
Taken as pupa,	June 10	June 17	Male
Taken as pupa,	August 22	August 25	Female

Chrysops niger Macquart

Only one individual of this species has been reared from collected larvae. It is difficult to explain why more have not been taken, since this species is exceedingly common in the adult stage. Further collections in situations other than the shores of ponds and streams

may reveal the larval habitat of this species. Stone (10) collected larvae of this species in a "boggy meadow fed by springs". A single larva was collected April 9, and a male adult emerged April 18.

Chrysops pikei Whitney

The larvae of this species have most frequently been taken from the banks of small water-courses. Only one specimen has been taken in the vicinity of stagnant water. The larvae were commonly taken from February until May, but later than that were difficult to find.

Table VII. **Chrysops pikei Whitney.** Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
February 24	April 26	May 2	Male
February 24	April 26	May 1	Female
February 24		April 27	Female
February 24		April 30	Female
February 24	April 25	May 1	Male
February 24	April 25	May 1	Male
March 31	May 21	June 2	Female
April 28	May 24	June 3	Female
April 28	May 28	June 5	Female
May 16	May 24	June 3	Female

Chrysops vittatus Wiedemann

Like **C. niger,** this species is common as an adult, but very difficult to find while in the larval stage. Our single specimen, which produced a female fly, was taken from the banks of a mill pond whose water is much colder than that of other ponds in the vicinity. The larva was taken July 1, 1930, pupated July 13, 1930, and emerged July 19, 1930.

The Genus Tabanus

Tabanus larvae have been taken during each month from February to December, and probably can be found any time of the year in the latitude of northern Arkansas. They are largest and therefore easiest to collect, during February, March, and April. While the majority of all larvae have been taken along the borders of ponds and streams, a few have been taken in the most diverse situations.

Larvae of this genus can be reared to the adult stage with little difficulty. They require only occa-

sional feeding, and a fairly moist environment.

Tabanus annulatus Say

This species is usually difficult to find, either in the adult or the larval stage. Recent collections of adults indicate that this fly is largely crepuscular, appearing about six o'clock p. m., and continuing its activity until sometime after dark. On two occasions it has been taken in company with **T. mexicanus,** a wholly crepuscular species[2]. Two white larvae, taken from decaying oak logs in the fall of 1928, produced adults of **T. annulatus** the following summer.

Table VIII. **Tabanus annulatus** Say. Seasonal history as obtained from collected larvae. 1929.

Date collected	Date emerged	Sex
October 19, 1928	May 24, 1929	Female
October 19, 1928	June 1, 1929	Male

Tabanus atratus Fabr.

The larvae of this large black fly have been taken in a variety of situations. Stagnant ponds, running streams, and cold springs appear to be equally favorable to its development. Larvae have been taken from floating algae in irrigation ditches serving rice fields, and from beneath moss on stones. A larva was once taken while the writer was digging in black lowland soil for white grubs.

Larvae taken early in the spring vary in length from one to five centimeters. This variation in size, however, is not an indication that the species requires more than a year to develop. Many of the smallest larvae produced adults during the summer following their collection, and subsequent investigation has shown that the species may progress from egg to adult during a period of 58 days in the latitude of northern Arkansas. Eggs of **T. atratus** have been taken continuously from June 19 until September 11, which probably explains the great variation in size of larvae taken in the spring.

The cannibalistic habit is highly developed in this species, and is probably an important factor limiting its numbers. In situations where the larvae are abundant, dead or partly devoured larvae are frequently taken. If the larvae from a single egg mass are left together in a small container, a few grow rapidly at the expense

2 This note is based on specimens and notes sent to me by Mr. W. A. Lee of DeQueen, Arkansas.

of the others, and usually after a period of about two weeks only one larva remains. Even in the natural environment it seems probable that a large percentage of the larvae from each egg mass dies in this manner. The larvae of **T. atratus** are undoubtedly an important factor in reducing the numbers of species associated with it in the larval stage.

Table IX. **Tabanus atratus** Fabr. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
February 24	May 29	June 16	Male
February 23	June 11	June 24	Female
February 23	May 29	June 14	Male
February 24	June 29	July 11	Female
March 17	June 14	June 25	Male
April 4	May 29	June 15	Female
May 31	June 9	June 24	Female
February 24	May 29	June 16	Male
March 17	June 5	June 22	Female
February 27	July 11	July 22	Male
April 4	May 29	June 16	Female
April 4	June 27	July 8	Female
March 17	August 6	August 19	Female
March 17	August 6	August 19	Female
March 17	June 5	June 21	Female
April 4	May 29	June 16	Female
April 4	June 18	June 30	Male
March 17	June 9	June 24	Male
April 7	June 29	July 11	Male
April 28	July 26	August 8	Male
April 28	July 23	August 3	Male
April 28	June 25	July 7	Male
April 28	July 18	July 28	Male
May 8	June 11	June 24	
May 8	July 1	July 11	Female
May 19	July 9	July 22	Female
April 9	July 19	July 30	Female
May 30	July 24	August 3	Male
May 30	July 27	August 6	Male
May 16	August 6	August 12	Female
April 28		September 12	Female

Tabanus cymatophorus Osten Sacken

This species is rare in Arkansas. Practically all

of the larvae have been taken from the banks of a cold, spring-fed pond. Only four have been reared to the adult stage.

Table X. **Tabanus cymatophorus** O. S. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
April 11	May 28	June 14	Male
April 11	June 19	June 30	Male
April 11	June 6	June 21	Male
April 5	August 3	August 12	Male

Tabanus lineola Fabr.

The larvae of this species have invariably been taken near stagnant water, and hundreds of its egg masses have been seen on vegetation growing in ponds or other stagnant bodies of water. Numbers of egg masses have been taken from young rice plants growing in flooded fields.

Tabanus lineola develops more rapidly than any other species thus far taken in Arkansas. Very small collected larvae have reached the adult stage within thirty days. Larvae reared from eggs have reached the pupal stage in a minimum of twenty-nine days.

Table XI. **Tabanus lineola** Fabr. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
February 12	May 28	June 14	Female
May 5	June 3	June 16	Female
May 5	June 7	June 19	Male
May 5	July 4	July 11	Female
May 5	June 10	June 21	Female
May 5	June 10	June 21	Female
May 5	June 5	June 19	Male
May 5	June 2	June 17	Male
April 23	June 6	June 14	Female
May 16	June 3	June 15	Female
May 16	June 3	June 14	Female
May 16	June 3	June 15	Male
May 8	June 7	June 20	Female
May 20	June 23	June 30	Female
Taken as pupa,	August 22	August 28	Male

Tabanus coffeatus Macquart

Three larvae of this small species have been taken in a spring-fed pond on a high hillside. Larvae have never been taken in the low marshy areas where the adults were abundant.

Table XII. **Tabanus coffeatus** Macquart. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
April 9	May 14	June 4	Female
April 9	June 9	June 23	Male
February 27	June 11	June 24	Male

Tabanus trimaculatus Palisot de Beauvois

Individuals of this species apparently differ considerably in habits. Larvae have been found in the banks of both spring-fed and stagnant ponds, and in both upland and lowland situations. Adult females have been observed ovipositing on grass at the water's edge, and on the leaves of trees seven feet above water. Full grown larvae are most easily found during March and April. The bulk of emergence occurs during June.

Table XIII. **Tabanus trimaculatus** P. de B. Seasonal history as obtained from collected larvae. 1930.

Date Collected	Date Pupated	Date Emerged	Sex
April 9	June 15	June 24	Female
April 9	June 2	June 16	Female
April 9	May 1	May 16	Male
April 4	June 9	June 21	Female
April 4	April 28	May 9	Male
April 4	May 28	June 13	Female
April 11	June 9	June 21	Female
March 17	May 26	June 10	Male

Tabanus vivax Osten Sacken

The eggs and larvae of this species have been taken in enormous numbers, but so far none have been reared to the adult stage. Egg masses always have been found on stones or driftwood protruding above the surface of rapidly flowing water. Masses are usually deposited separately, but occasionally several or even

hundreds of masses are placed on such a small area that their appearance is that of one enormous egg mass. One such mass, which was approximately one inch wide, twelve inches long, and five masses thick, was estimated to contain 120,000 eggs.[3] In one instance four females of **T. vivax** were observed ovipositing on a mass which already contained thousands of eggs. When deposited on stones, the eggs are usually placed in a small depression.

Larvae of this species have been found under small stones in running water two to six inches deep. When brought into the laboratory in mid-summer, all eventually died, even though kept in running water and well supplied with food. Hine (3) has reared adults of **T. vivax** from larvae taken in the fall. To obtain air, the larvae rise to the surface, and while the siphon projects through the surface film, the body of the larva forms an angle with the surface, much after the fashion of Culex larvae.

Tabanus wiedemanni Osten Sacken

The adult of this black species is comparatively rare in Arkansas, and its larva is represented in our collection by a single specimen taken in the muddy bank of a small brook, May 30, 1930. Pupation occurred June 25, 1930, and an adult female emerged July 7, 1930.

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AN INTERESTING NEW GENUS AND SPECIES OF CISTELIDAE (COLEOPTERA)

BY

H. C. FALL, Tyngsboro, Mass

KNAUSIA new genus

Oblong, shining; with sparse erect hairs which are arranged in single series on the elytral interspaces. Antennae rather short, stout; basal joint short, transverse; 2nd smaller, transverse; 3rd obconic and slightly longer than 1st and 2nd combined; 4th to 10th robust, broader than long, asymmetrically obconic, being more strongly developed exteriorly; 11th narrower, oval pointed. Terminal joint of maxillary palpus a little

longer than broad, gradually widened to apex which is oblique with the inner angle somewhat rounded. Eyes moderately large and prominent. Prothorax rounded in front as in Hymenorus, base as wide as the contiguous base of the elytra, basal margin strongly sinuate within the angles, which are strongly conically prominent. Structure of body beneath and legs virtually identical with Hymenorus, which genus it should follow in Casey's table.

Knausia crassicornis n. sp.

Narrowly oblong, sides of elytra straight and parallel in basal two-thirds; moderately convex, rufocastaneous throughout, integuments polished.

Head and thorax smooth, the latter with a few small vague lightly impressed punctures; Eyes (male?) separated by four-fifths their own width. Antennae scarcely twofifths as long as the body, very robust, distinctly attenuate, joints 4-8 widest.

Prothorax moderately transverse. Elytra scarcely wider than the thorax at base, twice as long as wide; striae consisting of completely unimpressed rows of very fine punctures, the intervals each with a single regular series of similarly fine punctures each bearing a fine suberect hair.

Propleura smooth and impunctate except for a few punctures along the antero-interior margin; metasternum with very few punctures; ventral segments 1-3 very sparsely and finely punctate. Hind tarsi short, scarcely more than two-thirds the length of their tibiae, basal joint subequal to the remainder. Length 6 mm.; width 2.3 mm.

The unique type of this remarkable species was received from Mr. Knaus who collected it at Deming, New Mexico, June, 1905. It remains in my collection. It is not unlikely that the peculiarly robust antennae may be characteristic of the male only.

The genus is dedicated with much pleasure to Dr. Warren Knaus of McPherson, Kansas; a valued correspondent for many years, and long recognized as one of the outstanding coleopterists of the great interior regions of our country.

THE INTERCHANGE OF SOIL AND SUBSOIL BY BURROWING INSECTS*

BY

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Insects studied under the heading of soil insects include those which undergo a part or all of their life cycle in the soil and those which make use of the soil in the construction of homes. These are of particular interest; first, because of the benefits which they derive from the soil as an environment, and second, because of the influence which they may have upon the soil.

Since the majority of insects pass some period of their life history in the soil, it becomes necessary for them to disturb the soil in their travels through it, and in so doing may affect this medium in many ways. Investigations have been made by agronomists and geologists to determine the processes involved in soil formation and in the deposition of new soil layers effected through the interaction of various soil-forming agencies. Consideration has also been given to those factors instrumental in causing soil erosion.

Where layers of soil have become fixed, weathering agents contribute very little toward mixing the soil with the subsoil on a given area. Plowing and other tillage operations expose a portion of the subsoil to the natural forces of weathering and incorporate it with the surface layers. Various agencies then aid in changing the unavailable plant nutrients present in the subsoil into available forms. Hence, any natural factor which would effect a gradual interchange of soil and subsoil would likewise be beneficial.

The data and observations herein submitted are not intended as a record of an exhaustive study on the subject of the interchange of soil and subsoil, but are intended to show that an interchange does take place and to indicate how this is done.

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1 The writer wishes to express his appreciation to Prof. Geo. A. Dean and other members of the department for their kind suggestions in the preparation of this manuscript.

REVIEW OF LITERATURE

Considerable study has been made in the science of animal ecology on the character of burrows, habitats, and habits of various burrowing insects, as well as other animals. A brief review of the literature on the interrelation of insects and soil shows that this phase of ecology is relatively new. In general, it can be said that the literature emphasizes the influence of environment upon the habits and distribution of insects without calling attention to the direct beneficial effect which burrowing insects may exert upon the soil. In a field near Cambridge, Mass., Shaler (1891) found ants so numerous that they transferred enough material annually to cover the surface of the soil with one-fifth of an inch of new soil. This is equal to about 30 tons per acre. Branner (1900) states that the mounds of various ants and termites of the tropics are of great size, numerous, and contain many tons of earth. Darwin (1883) emphasized the importance of earthworms in the formation of vegetable mould when he found that, in England, they brought to the surface ten tons of soil to the acre annually. Van Hise (1904) stated that animals aid in a mechanical way toward the disintegration of rocks by exposing new surfaces to weathering forces.

Buckles, of England, has two papers of value. One (1921) gives a preliminary survey of the soil fauna of agricultural land, while the other (1922) deals with the ecology of soil insects of the same habitat. In the latter he emphasizes the insect community and the distribution as determined by the food relations of the insects. McColloch and Hayes (1922) call attention to a reciprocal relationship existing between insects and soil, and that soil is important as an environment for insect life.

DESCRIPTION OF THE AREA

The spot under observation was a level area of land adjacent to the sand dunes which lie near the north bank of the Kaw river at Manhattan, Kansas. A growth of vegetation, consisting of grasses commonly found growing on sandy soils was present where the top soil had not been disturbed by tillage operations.

There were small areas where the top soil was too

sandy to support vegetation other than the common sandbur. Attempts had been made to bring the area under cultivation, but owing to frequent crop failures, the soil, for the most part, had been left undisturbed. Efforts to till the soil apparently had interfered very little with the activities of the insects, since a large number of burrows were present over the areas.

The surface layer of soil consisted chiefly of medium and coarse sand, ranging from 8 to 14 inches in thickness. Below this was a deposit of silt, varying in depth from 19 to 22 inches over a linear distance of three feet. This layer had been deposited by water at a time when the river overflowed the region, while the sand had been blown over it.

Beneath the silt is a deposit of very fine sand of unknown thickness. The line separating the two layers, although irregular, is distinct. This formation offered an excellent opportunity for the writer to study the effect of the burrowing action of several insects upon the interchange of soil. Numerous openings into the sand indicated the presence of burrows which either had been abandoned or were occupied by the residents that had completed them. The excavated material had been blown away or washed down by the rain.

METHODS

The present study was begun in the summer of 1924 and continued at intervals as time would permit. Five holes were dug two feet wide, three feet long and three feet deep, at different places over the area in order to ascertain the general distribution of the burrows over the region. A location for the hole was marked off and the first five inches of sand removed because many of the old burrows had been destroyed by tillage operations. The remainder of the sand and silt was removed in one-fourth inch layers in an attempt to trace the burrows.

Observations were made on insects encountered in both the silt and the sand, and data recorded on the number, diameters and lengths of the burrows present in the excavated area. It was necessary to make a separate study of those found in the silt from those encountered in the sand, since those studied in each layer were ordinarily made by different species of insects,

each of which had its particular burrowing habit.

A slender weed stem was placed in each open burrow in order to trace it to its extremity and to find the insect responsible for the work. Insects taken in the burrows were kept for identification, rearing purposes, and insectary observations on their burrowing habits.

Two cages were constructed, each consisting of two panes of window glass 12 by 18 inches, held in a vertical position by two upright grooved blocks 12 inches in length. The vertical pieces were nailed to a horizontal wooden base, two by four by twenty-four inches. The space between the two panes in each cage was a trifle wider than the body of the insect to be studied. One cage was filled with 11 inches of moist sifted silt, while the other was supplied with medium sand, taken from the area under observation.

The two species of beetles encountered during the digging operations were placed in these burrowing cages and observations made in regard to the character of the burrows constructed, the disposal of the excavated soil, and the manner in which the insects removed the soil. Eleven hymenopterous pupae were retained for rearing purposes and the collected beetles identified to species.

PRESENTATION OF DATA AND DISCUSSION

The observations made on the burrows and insects found in the two layers show that an interchange of soil and subsoil does take place in nature through the burrowing action of insects. Excavations and observations made in various places over the area at different times of the year, during a six-year period, show that the burrows are generally distributed and that an interchange of soil through the activities of insects has been in progress for several years.

One to five beetles, representing two species—**Harpalus erraticus** and **Geopinus fluviaticus** Csy.—were taken in each of the five holes during the process of removing the soil.

A total of 21 ground beetles were taken, 13 of which were in the burrows which they had constructed. The remainder were found beneath the surface in the

loose sand and could not be identified with their burrows. Two adult wild bees belonging to the family Andrenidae were reared from the hymenopterous pupae retained for rearing purposes. The silt had been forced upward into the overlying sand as the insect progressed downward due to the individual characteristics of the burrowing insects. When the sand was scraped away in layers, the burrows appeared as cross sections of black silt columns, varying in diameter from 0.125 to 0.50, with an average diameter of 0.34 inches for 50 representative silt burrows in the five holes. The burrows were distributed evenly throughout the sand layers. Those occurring in the silt appeared as columns of sand approximately the same diameter as the silt columns in the sand layer. These columns of sand were formed by the dry surface sand, filling the cavity in the burrows from which the silt had been excavated.

A study of the burrowing habits of **Geopinus fluviaticus** Csy. shows that this species, when confined in a burrowing cage, removes the soil for a distance varying from three to five inches deep and mounds it over the entrance to the burrow. As the beetle progresses downward, the soil is pushed back into the cavity from which the sand had been removed. As a result of this method of burrowing, no more soil is brought to the surface and the burrow is closed behind the beetle; consequently, as the insect passes from the sand layer into the silt, a column of the latter is pushed upward into the sand. There is no opportunity for the small cavity at the bottom of the burrow of this type to become filled with soil from the surface.

Similar observations made to determine the burrowing habits of **Harpalus erraticus** show that this species constructs a straight open burrow by pushing a small quantity of the soil to the surface at a time to form a mound at the entrance. This burrow being open its entire length affords an opportunity for the cavity to become partly filled with loose sand from the surface. Field observations on the character of the burrows in which the two species of beetles were taken verify the

studies made with them in the burrowing cages.

The wild bees found working on this area, constructed a burrow similar to the one described for **Harpalus erraticus.** Some of the burrows constructed by these solitary bees penetrated to a depth of 31 inches.

During the process of digging, sand was observed to fall into the burrow when the surface sand was disturbed. With the subsoil being carried to the top and dry surface sand filling the excavated burrow, a direct interchange of soil and subsoil takes place. Observations also show that this phenomenon has been taking place on this area for many years through the burrowing activities of various soil-inhabiting insects.

Tiger beetle larvae, dung beetles (**Canthon lecontei** Harold), and many other species were instrumental in constructing burrows on the area, but their burrows were not separated from the others or identified in the process of excavation. Their presence was recognized by the occurrence of small mounds of sand at the entrance to the burrow. Many of these insects failed to go below the sand layer, hence the soil brought to the surface could not be regarded as an exchange of soil and subsoil.

Observations indicate that all burrowing insects, which go below the ordinary plow depth of six inches will effect a gradual interchange of soil and subsoil in varying amounts. This process, without question, occurs in other localities where insects burrow, but owing to the difficulties involved in following the burrows where the soil and subsoil are similar in appearance, the effect is not so clear cut.

Following is a table showing the total number, average diameters, and average lengths for ten burrows found in the sand and silt.

TABLE I—Number and Dimensions of Burrows in Sand and Silt

Date	Burrows in sand on areas of six square feet.			Burrows in silt on areas or six square feet.		
	Number of burrows	Average lengths of ten burrows Inches	Average diameters of ten burrows Inches	Number of burrows	Average lengths of ten burrows Inches	Average diameters of ten burrows Inches
July 1924	42	4.5	0.31	31	10.2	0.37
July 1924	33	5.1	0.40	17	8.8	0.34
Nov. 1925	75	4.7	0.35	48	11.1	0.30
Nov. 1927	40	5.5	0.31	28	3.2	0.25
Aug. 1928	38	3.6	0.33	31	3.8	0.25
Average	45.6	4.68	0.34	29	7.42	0.30

An examination of the above table shows that in each area of six square feet studied, the average number of burrows occurring in the sand was 45.6, which is an average of 7.5 burrows to the square foot, while the average number of burrows in the silt was but 29, or an average of 5.8 burrows to the square foot. Seventy-five was the maximum number of burrows containing silt found in the sand layer in one hole, while 48 burrows were the largest number found in the silt. A number of six foot areas was examined other than those recorded in the table and none was found to be devoid of insect activity.

This difference in the number of burrows occurring within the two layers of soil is what one would expect since the majority of soil-inhabiting insects are to be found in the first foot. Observations show in this

study that the insects taken in the subsoil had gone down either for pupation or to escape the rigors of winter.

Observations showed further that the lengths and diameters of the ten burrows studied in each case were representative of the remainder of the burrows in the layers. Since it was such a difficult task to trace all the burrows encountered in each hole, it was deemed advisable to make a detailed study of ten representative ones rather than to attempt to excavate all of them. Many of the burrows progressed at an angle which made excavations more difficult.

As a general rule the burrows in the silt were vertical and became readily filled with sand when the sandy layer was disturbed. Calculations intended to show the amount of soil interchanged would be insignificant at the present time. However, if the burrowing continues on this area for a period of 50 or 75 years, a considerable amount of soil and subsoil will be interchanged. The amount at the present time is sufficient to show that insects play no small part in intermixing the soil when the various layers are fixed in their positions.

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